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WO 97/40255 A WO 96/28633 A US 6000480 A
US 4121806 A

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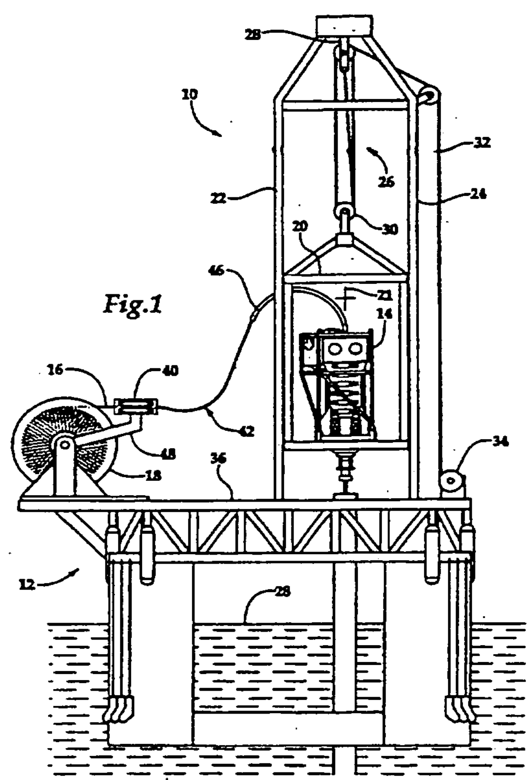
(54) Abstract Title
Method and apparatus for heave compensated drilling with coiled tubing

(57) In offshore drilling operations coiled tubing 16 stored on a reel 18 is lowered and raised into a wellbore by coiled tubing injector 14. A heave compensator frame 20, suspended from a mast 10, supports the coiled tubing injector 14 such that the vertical movement of the drilling platform 12 is compensated for.

Fig.1



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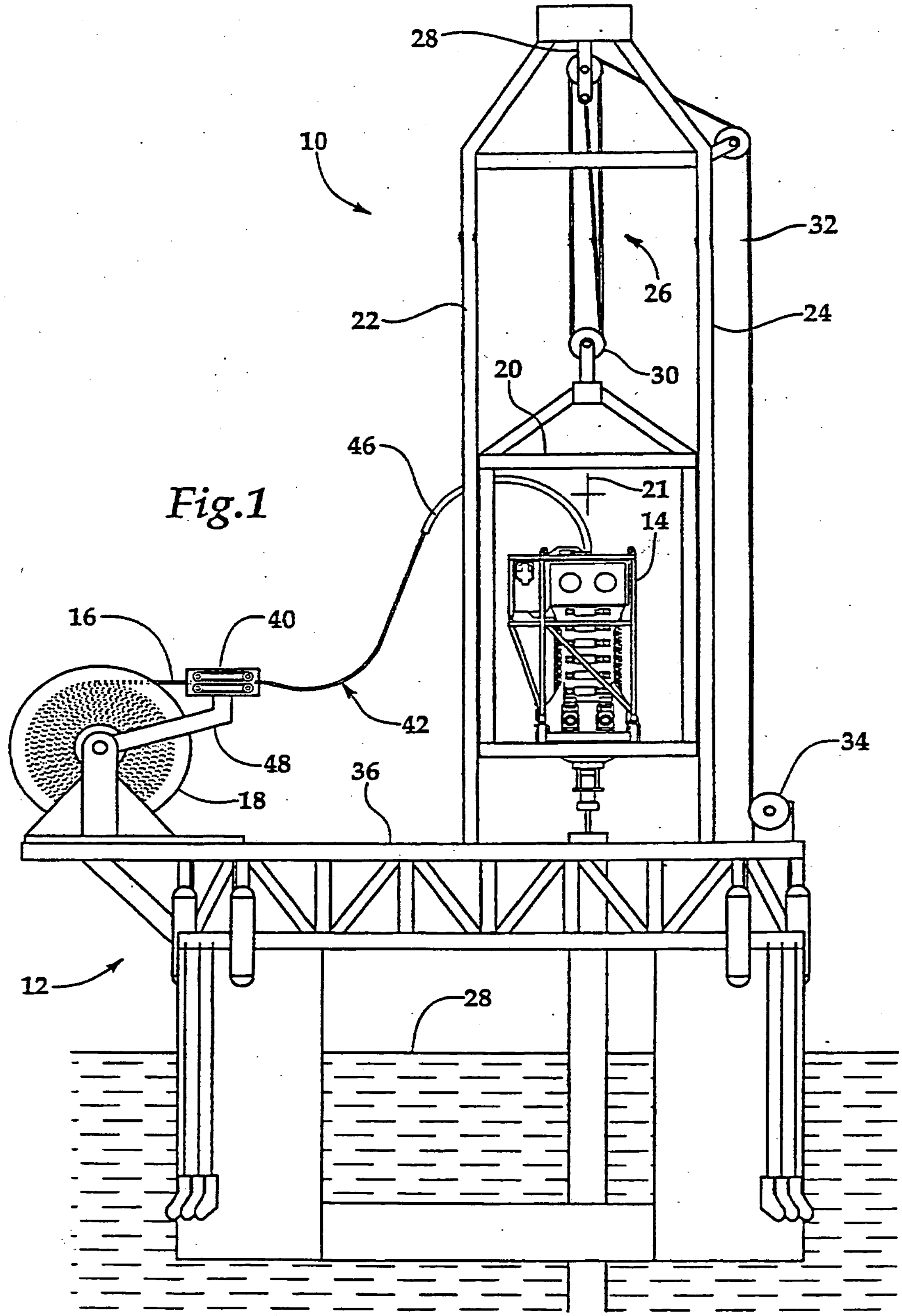

Fig.1

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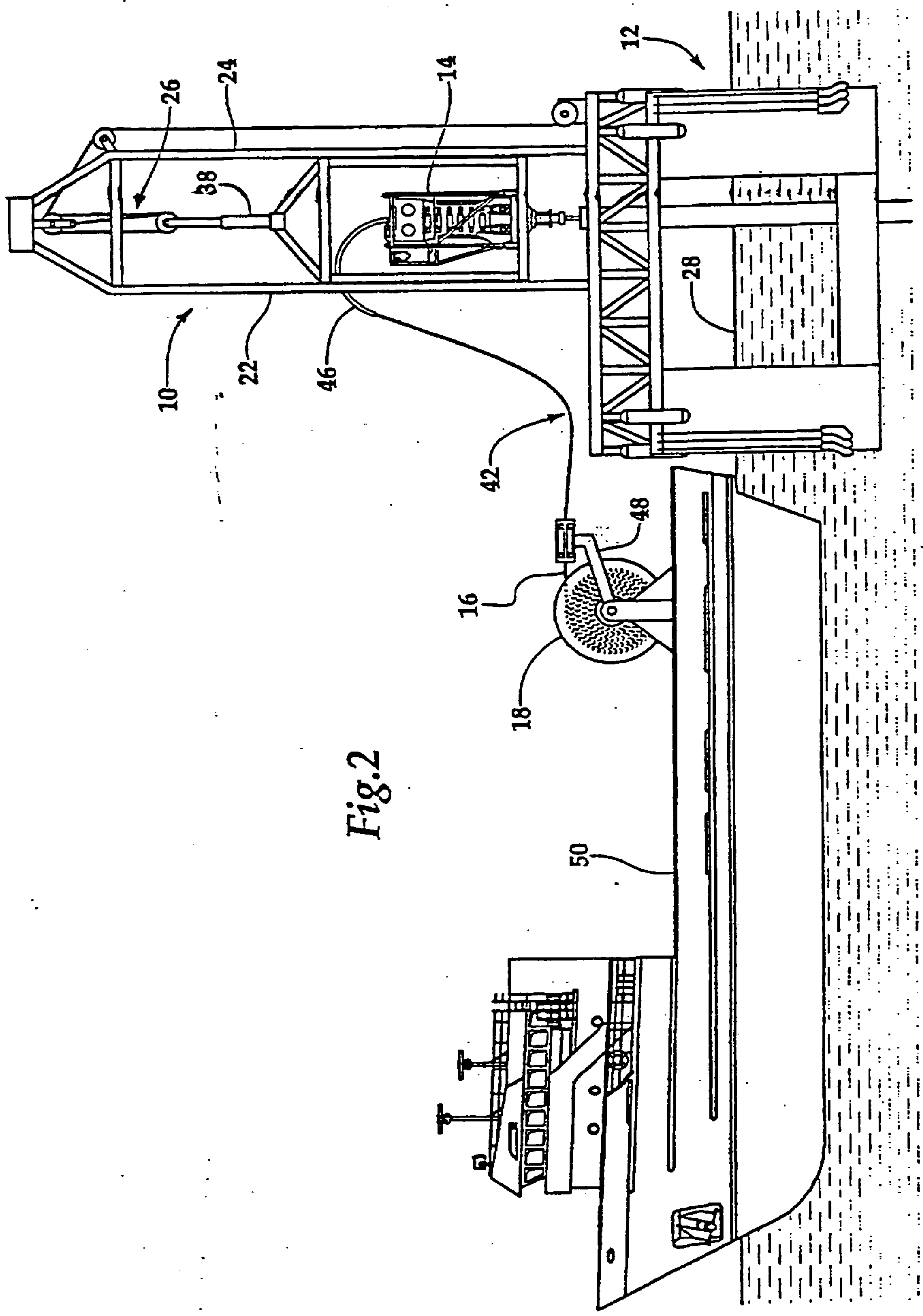

Fig.2

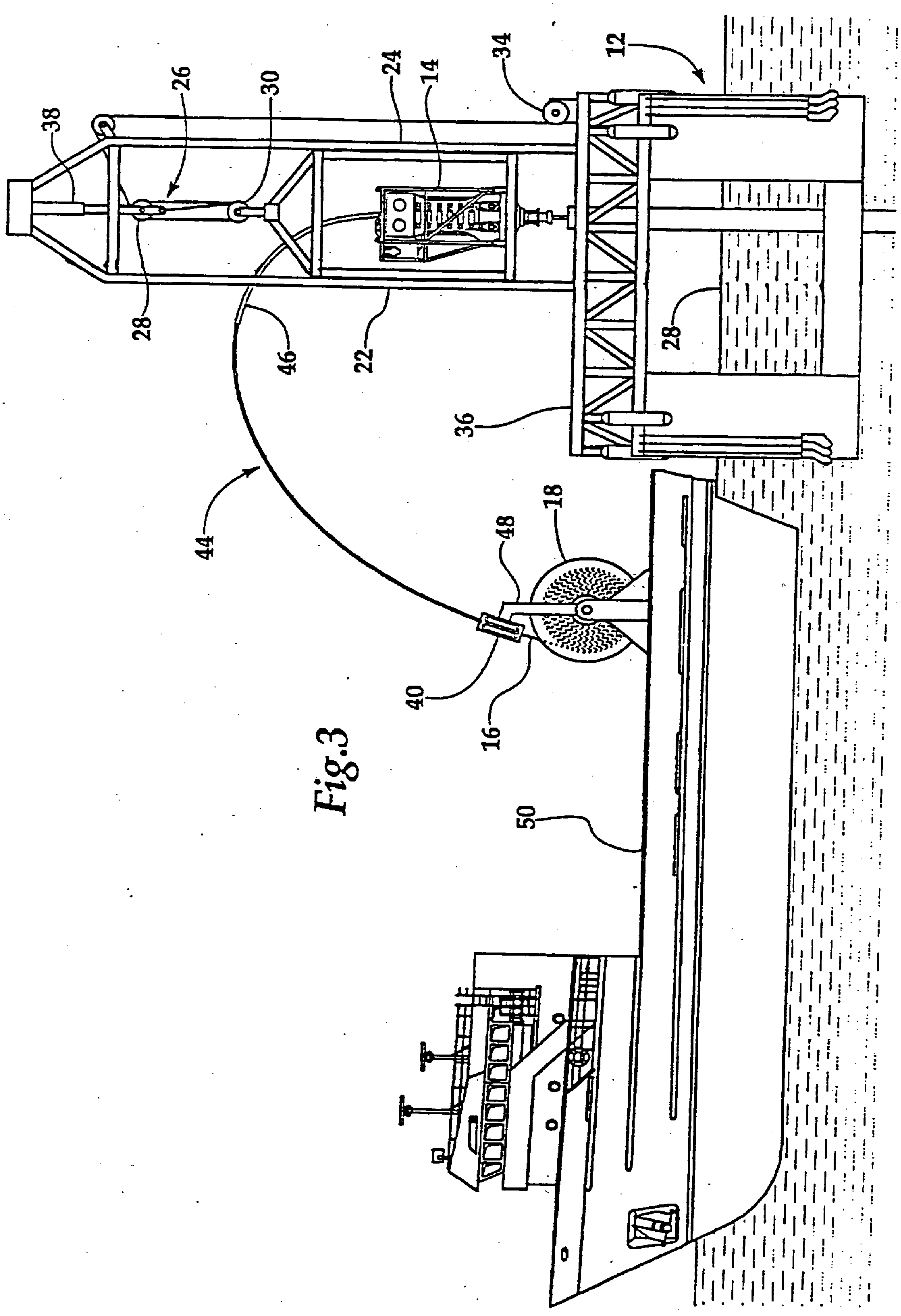

Fig.3

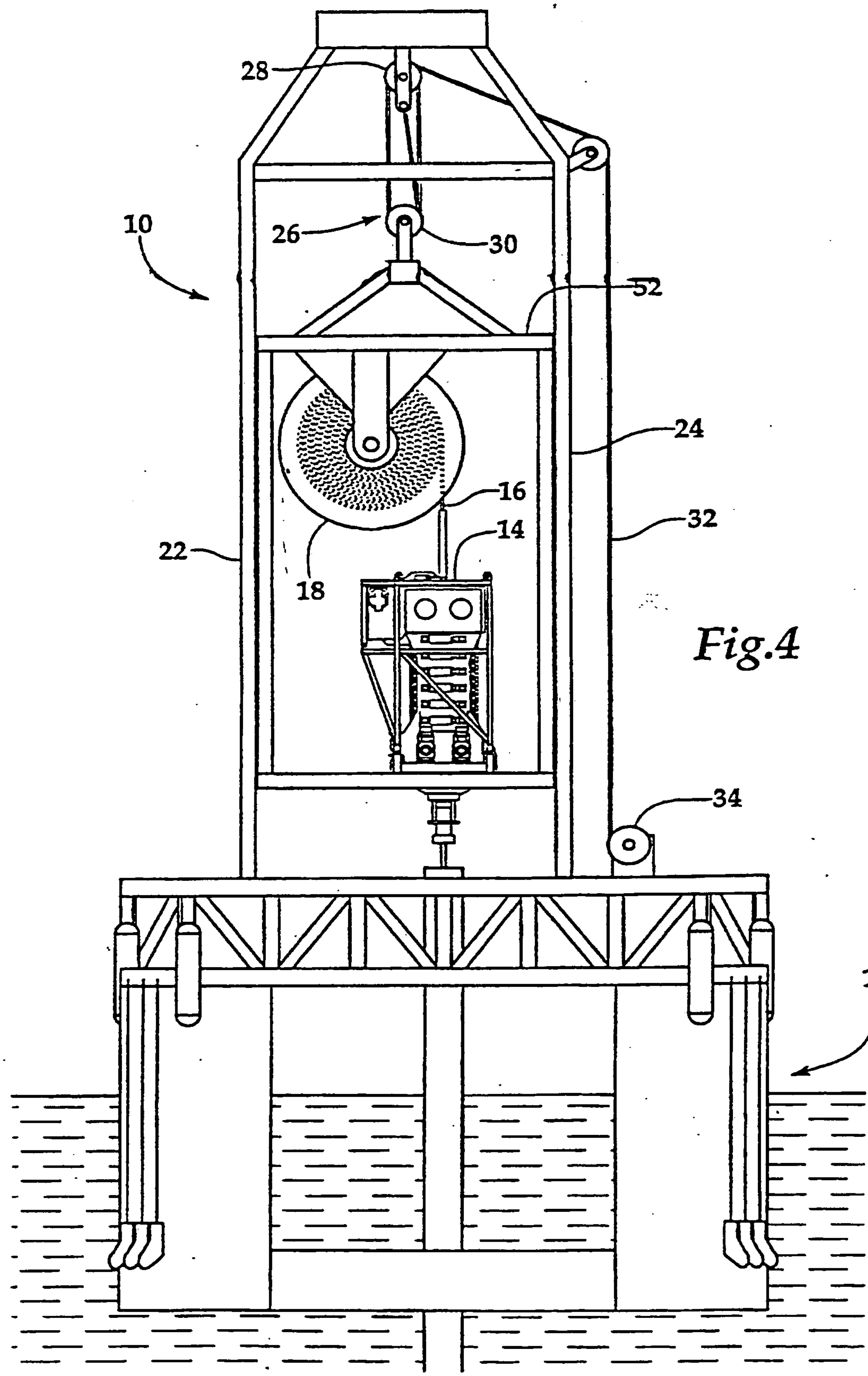

Fig.4

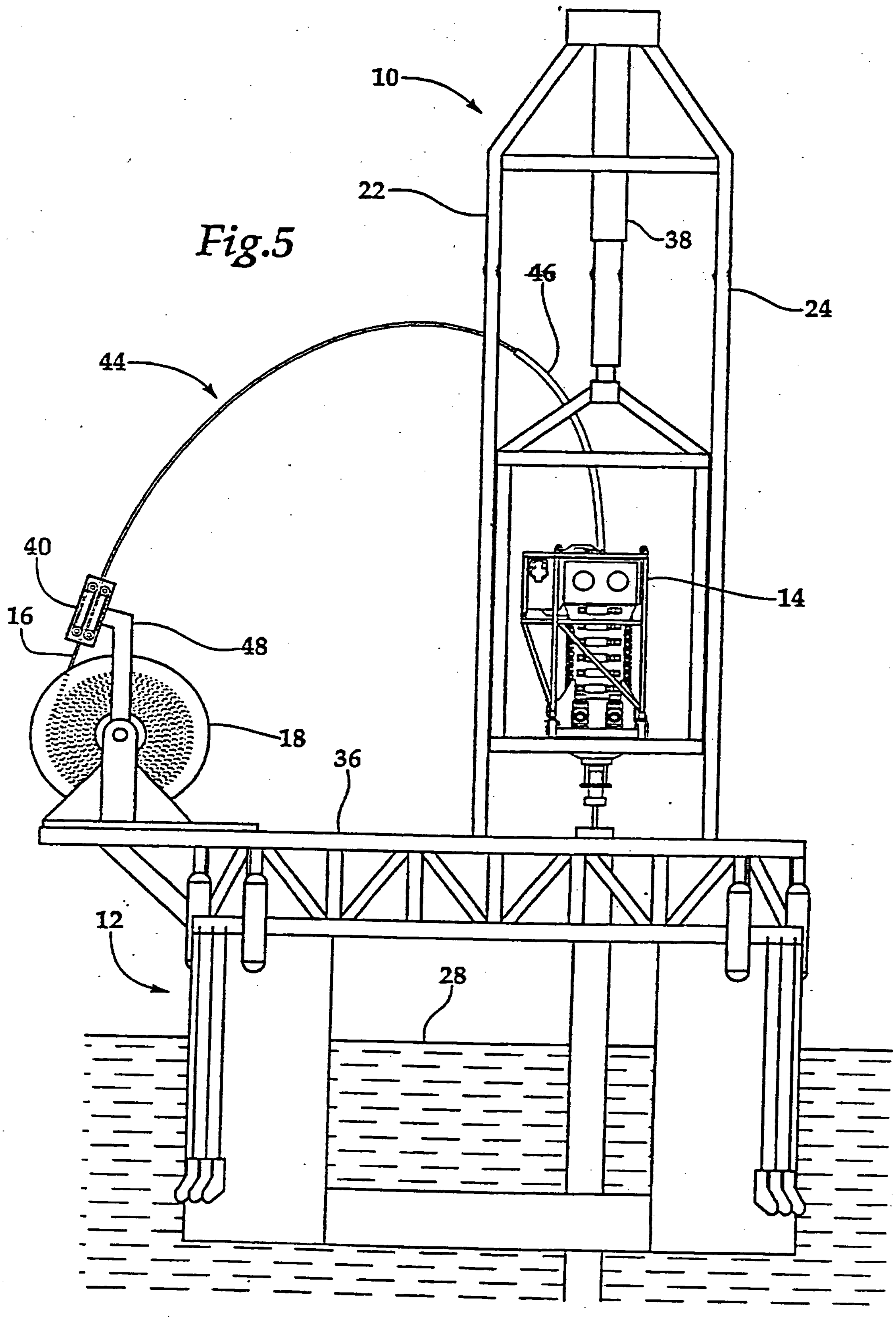

Fig.5

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METHOD AND APPARATUS FOR HEAVE COMPENSATED DRILLING WITH COILED TUBING

The invention pertains generally to the use of coiled tubing injectors on floating offshore platforms and specifically to methods for drilling using coiled tubing injectors on floating platforms.

Continuous pipe, generally known within the industry as coiled tubing since it is stored on a large reel, has been used for many years. It is much faster to run into and out of a well bore than conventional jointed straight pipe since there is no need to join or disconnect short segments of straight pipe. Coiled tubing "injectors" are used to run continuous strings of tubing into and out of well bores. The name "injector" was derived from the fact that, in preexisting well bores, the tubing must be literally forced or "injected" into the well through a sliding seal while overcoming the force produced by the well pressure acting on the cross-sectional area of the end of the tubing. Once a sufficient length of tubing has been injected into the well the weight of the tubing eventually exceeds the force produced by the pressure acting against the cross-sectional area of the tubing. Once the weight of the tubing overcomes the pressure-induced force, it must be supported by the injector. The process is reversed as the tubing is removed from the well. One method by which a continuous length of tubing can be either forced against pressure into the well, and be raised and lowered in the well bore is by continuously gripping a length of the tubing just before it enters the well bore. This is achieved in a tubing injector by arranging continuous chain loops on opposite sides of the tubing. The continuous chains carry a series of grippers that are pressed against opposite sides of the tubing. The chains are mounted on a frame, which sits on the drilling platform or is attached directly to the well head.

Coiled tubing has traditionally been used primarily for circulating fluids into the well and other work over operations, rather than drilling, because of its relatively small diameter and because it was not strong enough, especially for deep drilling. However, in

recent years, the availability of larger, stronger coiled tubing has made possible its use in drilling well bores and as permanent tubing in production wells. To drill, a turbine motor suspended at the end of the tubing and is driven by mud or drilling fluid pumped down the tubing.

The recent use of coiled tubing for drilling has brought about a new problem when used in the offshore environment. This problem is controlling the motion of the end of the tubing string, including the attached drilling tools, while the supporting vessel of structure rises and falls in response to heaving seas. Maintaining a steady load on the drill bit is crucial to effective and efficient drilling.

Traditional methods for coping with the heaving problem have been to control the motion of the tubing through the tubing injector. This method has the tubing cycling back and forth through the injector's gripping zone in response to the heaving. This method produces substantial cold working of the tubing string as it is plastically bent and cycled back and forth across a guidance arch above the injector and onto and off of a tubing storage reel. Additionally, considerable energy is required to rapidly change the direction of travel of the tubing storage reel, due to its high inertia, in response to the heave. Controlling the motion of the portion of the tubing between the injector's tubing guidance arch and the tubing storage reel, as the reel attempts to maintain constant tension on the tubing, can be difficult and dangerous.

An aim of the hereinafter described method and apparatus is to reduce stress on coiled tubing during offshore operations. In this regard a coiled tubing injector is supported on a floating platform using a heave compensator. Coupling the coiled tubing injector through a heave compensator avoids cyclical spooling and unspooling coiled tubing from a reel to compensate for heaving and thus the excessive stress placed on the coiled tubing resulting therefrom. Furthermore, it avoids the difficulties in operating a relatively massive storage reel and injector in a manner to compensate for heaving. Furthermore, the hereinafter described method and apparatus is able to be adapted to existing drilling equipment for use in off-shore drilling with coiled tubing, thereby minimizing capital investment and providing flexibility in choosing which drilling

method to use, and easily switching between drilling methods. The most cost-effective method of drilling for a particular well can thus be chosen and installed when required, resulting in reduced operating costs.

One aspect of various disclosed embodiments of the invention includes suspending a coiled tubing injector from a derrick through a heave compensator. Depending on the particular type of heave compensator used, the heave compensator is coupled between the coiled tubing injector and the derrick, between the top of the derrick and a draw works assembly that is supporting the injector, or between the top of the derrick and the injector. The draw works itself could, alternately, be heave compensated and connected directly to the injector. Coupling the coiled tubing injector through a heave compensator avoids the stress on the coiled tubing associated with cyclical spooling and unspooling the coiled tubing from the reel, and the operation of the relatively massive storage reel and injector to compensate for movement of a floating platform on which the derrick located. Furthermore, suspending the injector from a derrick allows the injector to be raised in order to attach bottom hole assemblies and other tubing end devices to the end of the coiled tubing once it has been threaded through the injector and before it is inserted into the well bore. It also enables the injector to be utilized in conjunction with tall lubricators or risers.

An aspect of another disclosed embodiment is to provide an extra semi-relaxed length of tubing between the tubing storage reel and the injector. The extra semi-relaxed tubing length between the tubing storage reel and injector allows the injector and tubing storage reels to move relative to one another without the need to spool tubing onto and off of the storage reel, or through the injector in response to heave as is done using conventional methods. The tubing storage reel has a tensioning injector mounted directly on its framework that provides the necessary tension to maintain proper spooling of the tubing on the reel. The two injectors thus move the tubing in unison to maintain the same length of tubing between the tubing storage reel and the injector mounted in the derrick. This means the length of tubing between the storage reel and injector remains constant. The extra length of tubing allows the injector to move relative to the storage

reel with less stress in the coiled tubing string as compared to the conventional methods, in which Cyclical stressing and straining of the tubing string can lead to premature fatigue in the wall of the coiled tubing.

These and other aspects of various embodiments incorporating the invention, and their respective advantages, are described below in reference to the appended drawings, in which:

FIG. 1 is a schematic illustration of a derrick used for drilling well bores, having an injector hanging from the derrick, through a heave compensator, for running coiled tubing wound on a reel located on a drilling platform;

FIG. 2 is a schematic illustration of a derrick used for drilling well bores, having an injector hanging from the derrick, through a heave compensator, for running coiled tubing wound on a reel located on a boat floating beside a floating platform on which the derrick is located;

FIG. 3 is a schematic illustration of an alternate embodiment to FIG. 2;

FIG. 4 is a schematic illustration of a floating platform with a derrick for drilling well bores having a coiled tubing injector and a reel wound with coiled tubing hanging from the derrick, through a heave compensator; and

FIG. 5 is a schematic illustration of an alternate embodiment to FIG. 1.

In the following description, like numbers refer to like elements.

Referring to FIGS 1, 2, 3, 4 and 5, suspended from mast or derrick 10 is a coiled tubing injector 14. The coiled tubing injector lowers and raises coiled tubing 16 into a well bore (not shown) for drilling or other down-hole operations. The coiled tubing is wound on a storage reel 18. The derrick as shown is of a type that can also be used for drilling well bores or performing down-hole operations using jointed pipe. Furthermore, derrick 10 is operating offshore, and is thus shown atop floating drilling platform 12. However, the tubing injector 14 can also be operated from other types of floating structures, including for example semi-submersible platforms, ships and boats. The term "floating platform," as used herein, refers to any sort of floating structure, including

those that are semi-submersible, that are affected by heaving in offshore environments. Coiled tubing injector is mounted within a traveling frame 20 (Figs. 1, 2, 3 and 5) or 52 (Fig. 4), which in turn is hung from derrick 10. The traveling frame is preferably constrained against movement in all directions except along a vertical axis 21. In an offshore environment, horizontal movement might be caused by waves on the surface of water 28. The traveling frame 20 cooperates with one or more vertical guides. In the illustrated embodiments, vertical members 22 and 24 of derrick act as rails that constrain movement of the traveling frame 20. However, any number of different configurations of vertical rails or tracks can be used to form guides to achieve the result of confining the frame to movement along the vertical axis during down-hole operations. On drilling rigs incorporating top drives, existing top drive guide rails can be used. This means the top drive can be removed and the drilling injector framework installed with the minimal of effort.

Heaving caused by waves can subject floating platform 12 to considerable vertical movement. Vertical movement of a drill string during drilling operations is not desirable since it is advantageous to maintain a near-constant weight on the drill bit. Maintaining constant weight on the drill bit promotes more efficient drilling and thus higher penetration rates. A variety of methods have been employed to compensate for vertical movement of drilling platforms at sea and thus, in effect, isolate a conventional jointed, drill string from the effects of heaving. These methods typically use a mechanical or hydraulic (or combination thereof) system known as motion or heave compensator. There are many types of heave compensators. They can be passive, semi-active or active.

In each embodiment respectively illustrated in Figs. 1-5, a heave compensator is coupled between the coiled tubing injector 14 and derrick 10. Alternately, a heave compensator can be mounted on the floor of the floating platform, and the coiled tubing injector mounted on top of the heave compensator. By supporting the coiled tubing injector 14 on the floating platform with a heave compensator, such as by coupling the derrick 10 and the coiled tubing injector 14 through a heave compensator or mounting

the coiled tubing injector on top of a heave compensator mounted on the floor of the floating platform, the heave compensator is able to maintain the coiled tubing injector in a substantially fixed position relative to the well bore. As floating platform 12, heaves or otherwise moves relative to the well bore, the heave compensator will move the coiled tubing injector along the vertical axis, relative to derrick 10, to compensate for the movement of the derrick caused by the heaving. In the illustrated embodiments, traveling frame 20, in which the coiled tubing injector is mounted, will move up and down within the derrick 10 along the derrick's vertical axis, which is designated in Fig. 1 by axis line 21.

Referring now to only FIGS. 1, 2, 3 and 4, the derrick 10 includes draw works 26. The frame 20 is hung from the draw works. The draw works include a crown block 28 connected to the top of the derrick and a traveling block 30 coupled with the traveling frame 20. No particular type of coupling between the traveling frame and traveling block is required. An adaptor can be used, if necessary, to attach the traveling frame to existing draw works. The draw works also includes a cable having one end wrapped around the drum of winch 34. In the embodiments illustrated by Figs. 1 and 4, the winch is part of, incorporates or includes (*e.g.* be controlled by) a heave compensation system or compensator. For example, the heave compensator operates the winch to lower and raise the coiled tubing injector to compensate for heaving. Although the winch is shown mounted on floor 36 of the floating platform 12, it could also be mounted on top of the derrick. Alternately, hydraulic heave compensator 38, which uses a piston and cylinder to generate forces that allow the derrick to move independently of a drill string, can be coupled between the between the derrick and crown block, as shown in Fig. 3; between the traveling block and coiled tubing injector 14 as shown in Fig. 2; or, referring now to FIG. 5, between the coiled tubing injector 14 to the derrick 10 without using a draw works, as shown therein.

Referring now to FIGS. 1, 2, 3 and 5, as the coiled tubing injector 14 moves up and down within derrick 10, it is also moving with respect to storage reel 18. The reel is tensioned to provide a bias that prevents uncoiling of the coiled tubing from the reel.

However, in order to accommodate the movement of the coiled tubing injector 14 with respect to the reel 18 and avoid excessive bending of the tubing that would place undue stress on it, an extra amount of coiled tubing must be unwound. This extra amount of coiled tubing results in a "loop" being formed in a portion or segment of the coiled tubing extending between the reel 18 and the coiled tubing injector 14. A tensioning injector 40 is used to hold the coiled tubing so that tensioning on the reel 18 can be transferred only to the portion of the coiled tubing wound on the reel and not to the loop.

Two types of loops can be used: a sagging loop 42 (Figs. 1 and 2) and a standing loop (Figs. 3 and 5). Depending on the type of loop, a different type of gooseneck is used to provide the proper support for the coiled tubing as it transitions into the coiled tubing injector 14. Gooseneck support 46 (Figs. 1 and 2) is used with a sagging loop; gooseneck support 48 (Figs. 3 and 5) is used with a standing loop. Furthermore, as shown in Figs. 1 and 2, the axis of the tensioning injector 40, which is defined by the portion of the coiled tubing passing through the injector, is oriented generally horizontally with respect to axis 21 to establish sagging loop 42. As shown in Figs. 3 and 5, the axis of the tensioning injector is oriented between a horizontal axis and a vertical axis, with respect generally to the axis 21 of the derrick, to establish standing loop 42. The tensioning injector is mounted on a support arm 48 that pivots about reel 18 so that the orientation of the tensioning injector can be easily adjusted in the field.

Furthermore, it is preferable that the axis of the tensioning injector 40 be always oriented with respect to the reel such that the coiled tubing, as it is being taken off the reel, remains relatively straight and does not bend before it enters the tensioning injector. The injector therefore pivots on the arm 48 as the outer diameter of the tubing coil on the reel 18 changes, such that the axis of the injector remains tangential to an outer circumference of the coil of tubing.

The reel 18 can be placed either on the same floating platform as the derrick or a separate floating platform such as boat 50. Boat 50 can act as a tender, bringing reels of tubing out to the floating platform, as they are needed, without having to unload the reel on to the floating platform.

Referring now to FIG. 4, reel 18 is, alternatively, mounted with the coiled tubing injector 14 in a common frame 52. By placing the reel and coiled tubing injector in a common frame, the injector can be heave compensated without placing additional stress on the coiled tubing. However, due to the close proximity of the reel with the coiled tubing injector, the reel is preferably mounted within the frame 52 in a manner that avoids excessive bending of the coiled tubing after it has been unreeled. Preferably, the axis of the coiled tubing within the injector 14 should always remain tangential to the coiled tubing on the reel. A method and apparatus for reducing bending of coiled tubing as it is unreeled, and before it enters and injector, is disclosed in U.S. Patent No. 5,660,235, of Sola, dated August 26, 1997, which is incorporated herein for all purposes.

The forgoing embodiments are but examples incorporating use of the invention. Modifications, omissions, rearrangements and other changes may be made to the embodiments without departing from the invention as defined by the appended claims.

CLAIMS

1. A drilling apparatus comprising:

a floating platform;

a reel of coiled tubing;

a heave compensator coupled with the floating platform;

and a coiled tubing injector supported by the heave compensator, whereby the coiled tubing injector remains in a substantially fixed position with respect to a well bore when the floating platform heaves.

2. The drilling apparatus of Claim 1, wherein

a derrick is mounted on the floating platform; and

the coiled tubing injector is suspended from the derrick, through the heave compensator.

3. The drilling apparatus of Claim 2, wherein the coiled tubing injector is coupled to a draw works hanging from the derrick.

4. The drilling apparatus of Claim 3, wherein the draw works includes the heave compensator.

5. The drilling apparatus of Claim 2, wherein the coiled tubing injector is coupled to a heave compensator, and the heave compensator is coupled to the Derrick.

6. The drilling apparatus of Claim 2 wherein the coiled tubing injector is mounted within a frame, and the frame is hung from the derrick.

7. The drilling apparatus of Claim 2, wherein the reel is mounted within the frame for common movement with the coiled tubing injector.

8. The drilling apparatus of Claim 1, wherein the reel is also supported by the heave compensator.

9. The drilling apparatus of any one of the preceding claims, further comprising a tensioning injector disposed between the coiled tubing injector and the reel, through which coiled tubing from the reel passes before it enters the first coiled tubing injector.

10. The drilling apparatus of Claim 9 wherein coiled tubing between the tensioning injector and the coiled tubing injector forms a loop for accommodating movement of the coiled tubing injector relative to the tensioning injector.

11. A method for running coiled tubing down a well bore comprising:
supporting a coiled tubing injector with a heave compensator on a floating platform;
feeding coiled tubing from a reel to the coiled tubing injector; and
operating the tubing injector to lower the coiled tubing into the well bore.

12. The method of Claim 11 wherein the coiled tubing injector is suspended from a derrick, through the heave compensator.

13. The method of Claim 12 wherein the coiled tubing injector is mounted within a frame, and wherein the method further comprises maintaining vertical alignment of the movement of the injector with the derrick during movement of the coiled tubing.

14. The method of Claim 13 wherein the reel is mounted within the frame.

15. The method of any one of Claims 11 to 14, further comprising maintaining a loop in the coiled tubing between the reel and the coiled tubing injector to allow for vertical movement of the coiled tubing injector relative to the reel.

16. The method of Claim 15 wherein maintaining the loop includes operating a tensioning injector in unison with the coiled tubing injector, the tensioning injector being located in a fixed position between the reel and the loop.

17. The method of Claim 16 wherein the loop is a standing loop.

18. The method of Claim 16 wherein the loop is a sagging loop.

19. The method of Claim 11 further comprising supporting the reel with the heave compensator.

20. A drilling apparatus substantially as herein described with reference to the accompanying drawings.

21. A method for running coiled tubing down a well bore, the method being substantially as described herein with reference to the accompanying drawings.

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Application No:	GB 9925440.1	**Examiner:**	David Hotchkiss
Claims searched:	1 - 20	**Date of search:**	29 February 2000

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.R): E1F (FAY, FJG, FJS)

Int Cl (Ed.7): E21B

Other: Online: WPI, EPODOC, PAJ

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X,E	US 6000480 A	(Mercur Slimhole Drilling Intervention AS) Whole document especially Column 1 lines 5 - 10 and Column 2 line 55 - Column 3 line 3	X: 1, 8, 11 & 19
A	US 4121806 A	(Elf Aquitaine) Whole document	
A	WO 96/28633 A	(Baker Hughes Incorporated) Whole document	
A	WO 97/40255 A	(Baker Hughes Incorporated) Whole document	

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.